Vermiculture Biotechnology

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Vermiculture Biotechnology For

— Environmental Protection
— Sustainable Agriculture
— Wasteland Development

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1. What Is Vermiculture Biotechnology ?

1.1 **Biotechnology** essentially involves large-scale applications of bio-systems for economic and efficient bio-processing of materials to produce value-added bio-products.

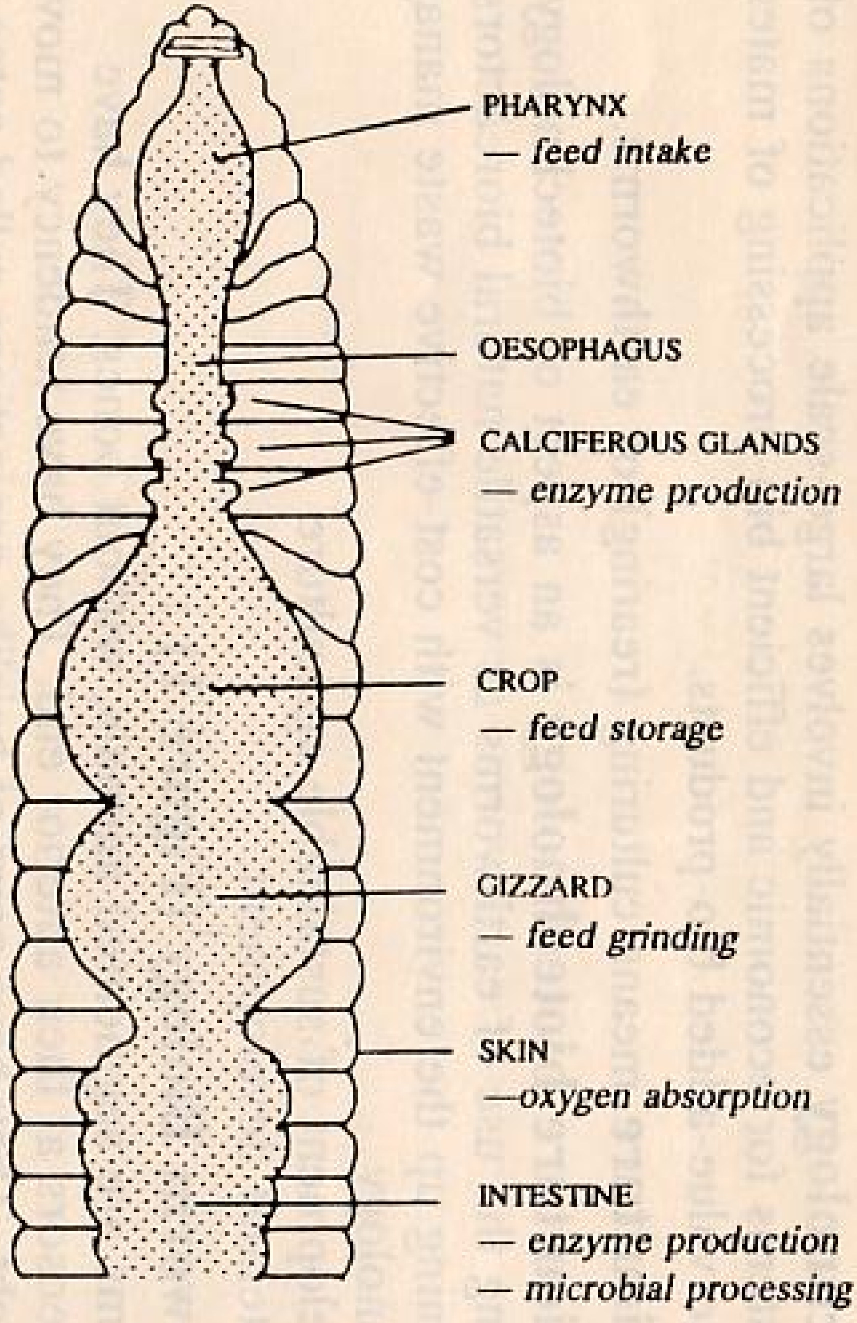
1.2 **Vermiculture** means culturing (rearing) of earthworms.

1.3 **Vermiculture biotechnology** is an aspect of biotechnology involving the use of earthworms as versatile natural bioreactors for

— cleaning up the environment with cost-effective waste management technology
— development of sustainable agriculture
— wasteland development.

1.4 Earthworm Biology (Figure 1) :

Worms are segmented animals, without bones. They have photosensors at their anterior end. They have tendency to move away from light. They have pairs of hairlike projections called setae on each segment. Locomotion is by means of a series of contractions and expansions, aided by setae. Clitellum, a swollen band near the front end indicates that the worm is sexually mature.



EARTHWORM

The Natural Tubular Bioreactor

Figure 1

Worms have a muscular gizzard, similar to that in birds. Small grains of sand and mineral particles lodge in the gizzard. Food is finely ground in the gizzard. Grinding to a size of 2-4 microns takes place. This increases the surface area, for the microbial action, in the gut of the worm.

Worms are hermaphrodites (bisexual) and they can double their population in a month, given ideal conditions of temperature, moisture, food,etc. Their population is controlled by the availability of food supply.

Worms may die due to transport shock and due to change of environment. Hence live worms should not be dug out from the soil and transferred to a new environment.

Instead, vermicastings, an effective biofertilizer, produced by the worms should be used as a vermiculture. Vermicastings harbour earthworm cocoons and a wide spectrum of beneficial microflora. Earthworms, hatched in the altered environment, are able to adapt better to the new environment.

Earthworms of proper variety should be used for each individual purpose. Burrowing-type worms, with their digging muscles, can burrow as deep as 3 m and protect themselves from drought conditions.

1.5 Earthworm Microbiology :

The gut of an earthworm acts as a bioreactor, providing ideal conditions of temperature, pH and oxygen concentration for speedy growth of useful aerobic (oxygen-demanding) bacteria and actinomycetes, thus resulting in the microbial density– about 1,000 times greater than in the surrounding soil.

These microorganisms produce useful compounds like antibiotics, vitamins, plant-growth hormones, etc.

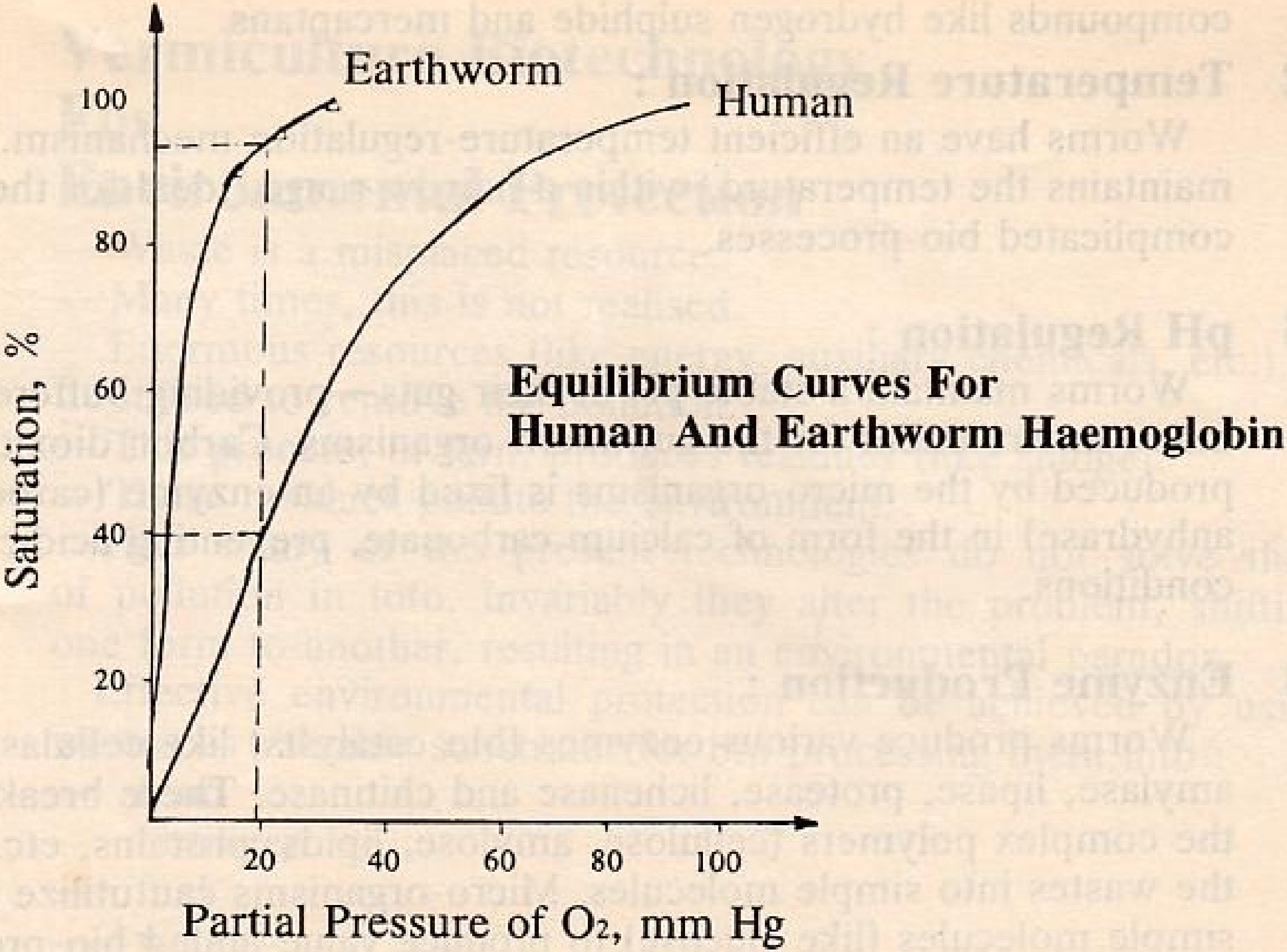
They also outcompete pathogens, resulting in pathogen destruction.

1.5.1 Oxygen Supply (Figure 2):

Blood-haemoglobin, in worms, shows greater affinity towards oxygen than human haemoglobin. Their haemoglobin gets saturated with oxygen, even when deep in the soil, where oxygen partial pressure (concentration) is low.

Rich oxygen is provided to the gut micro-organisms, resulting in speeding up of the various bio-processes. This mechanism maintains aerobicity in a decomposing mass of organic wastes.

Oxygen-rich micro-environment eliminates anaerobic micro-organisms, preventing formation of foul smelling, abnoxious



EARTHWORM AERATION

Figure 2

compounds like hydrogen sulphide and mercaptans.

1.5.2 Temperature Regulation :

Worms have an efficient temperature-regulation mechanism. This maintains the temperature, within a narrow range, ideal for the complicated bio-processes.

1.5.3 pH Regulation :

Worms maintain a stable pH in their guts— providing buffered micro-environment for the gut micro-organisms. Carbon dioxide produced by the micro-organisms is fixed by an enzyme (carbonic anhydrase) in the form of calcium carbonate, preventing acidic conditions.

1.5.4 Enzyme Production :

Worms produce various enzymes (bio-catalysts) like cellulase, amylase, lipase, protease, lichenase and chitinase. These break down the complex polymers (cellulose, amylose, lipids, proteins, etc.) from the wastes into simple molecules. Micro-organisms can utilize these simple molecules (like glucose) to produce value-added bio-products.

2. Vermiculture Biotechnology For Environmental Protection

— Waste is a misplaced resource.
— Many times, this is not realised.
— Enormous resources (like energy, auxiliary chemicals, etc.) are utilised to remove the pollution.
— This process, in turn, produces residues (like sludge).
— These residues pollute the environment.

Thus many of the present technologies do not solve the problem of pollution in toto. Invariably they alter the problem, shifting it from one form to another, resulting in an environmental paradox.

Effective environmental protection can be achieved by using diverse wastes as valuable substrates for bio-processing them into :

— food
— fertilizer
— fuel
— water.

WASTE IS A MISPLACED RESOURCE

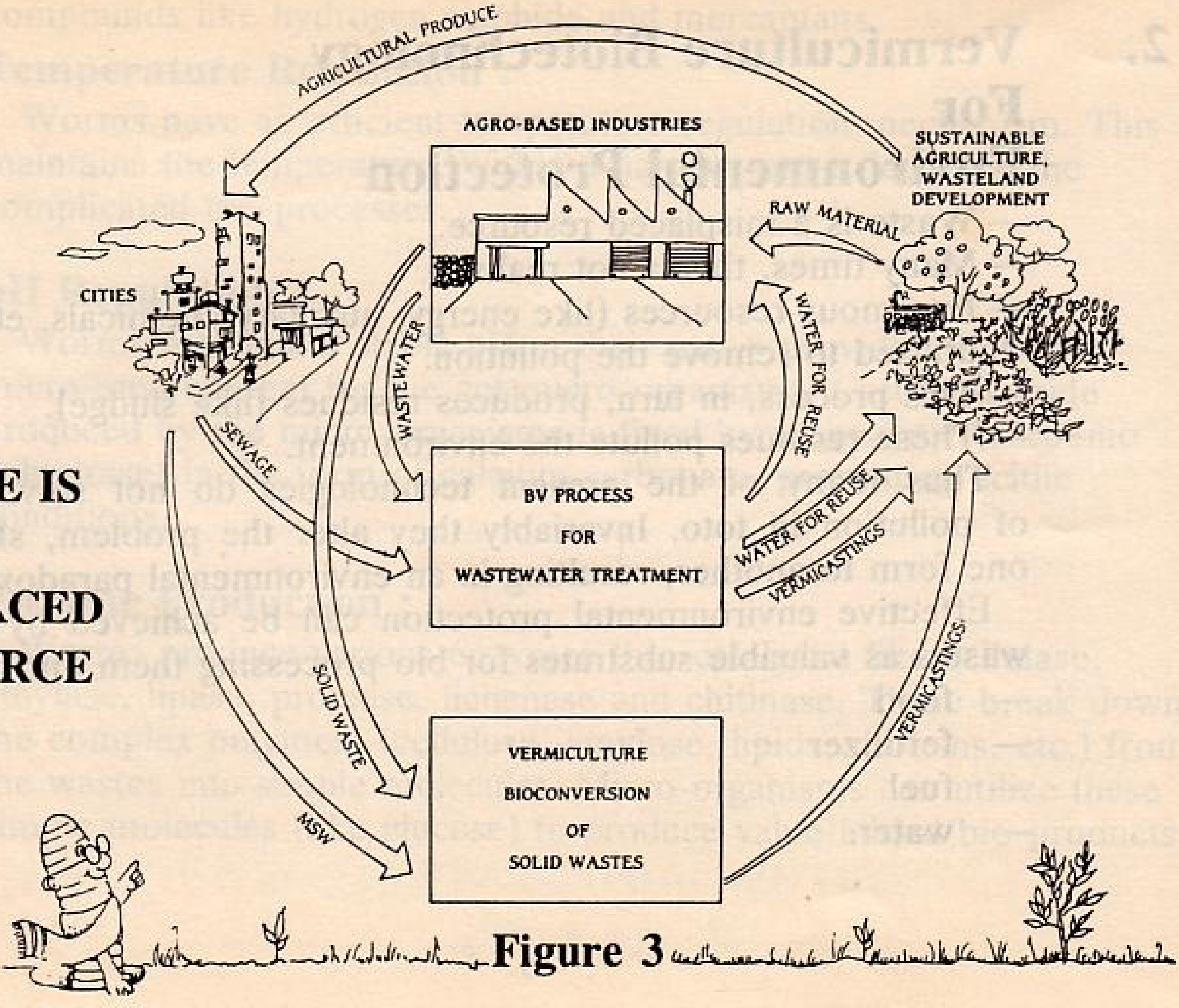


Figure 3

Cost-effective bio-processing is possible by harnessing the natural bioreactors, such as earthworms, for achieving this without the external inputs like :

— energy for aeration
— auxiliary chemicals.

2.1 Solid Wastes Management :

2.1.1 Municipal Solid Wastes (MSW) :

Municipal solid wastes, or garbage, is a valuable resource.
When neglected, it becomes a waste, creating pollution.
MSW consist of

— Non-biodegradable resources : glass, plastics, metals,etc.
— Biodegradable resources : paper, organic wastes.

MSW produced per person per day and the analysis thereof depends upon the standard of living :

Higher standard - more wastage - more non-biodegradables
Lower standard - less wastage - less non-biodegradables
Hamburg, Hongkong, Singapore - 4 kg/d MSW per person
New York - 2 kg/d MSW per person
Bombay, Calcutta - 600 g/d MSW per person

The city of New York produces 30,000 tons/d MSW, highest in the world.

Bombay produces 6,000 tons/d MSW and spends Rs. 1,000 million each year just on collection & transport to land-fills.

India generates, annually, 25 million tons MSW.

Resource recycling is the only sensible way to tackle the problem of MSW.

Japan has the world's most successful recycling programme, with about 65 percent of municipal solid wastes being recycled.

Metals, glass, plastics and paper should be separated at source and recycled to the respective industries. Table 2.1 shows the benefits achieved through such recycling. This also has a potential of providing gainful employment to the ragpickers (resource recycling agents).

Table 2.1 Benefits Achieved By Recycling

	Reduction Achieved (%)			
	Aluminium	Steel	Paper	Glass
Energy Use	90-97	47-74	23-74	4-32
Air Pollution	95	85	74	20
Water Pollution	97	76	35	—
Water Use	—	40	58	50

[Source : Kharbanda, O. P. and E. A.Stallworthy (1990), Waste Management, Gower, Hants, England.]

"Where there is muck
there is high technology.
Rich countries will
grow richer in garbage too."

-The Economist
April 6, 1988

Vermiculture biotechnology can be used to handle biodegradable organic wastes in 3 ways :

1. Bio-processing Under A Tree :
Those who have a garden, should apply 5 kg vermicastings below a tree and apply a 100 mm layer of household organic wastes as a mulch. The mulch reduces water requirements of the tree, as evaporation from the soil is reduced. It also serves as a food for the soil organisms. Mulch, when consumed, produces a rich organic fertilizer with earthy smell. As the old layers get consumed new layers are topped up. Trees too show healthy growth without any digging and chemical fertilizers. Garden space of 1 m^2/family is required to consume all the biodegradable wastes generated.

2. Bio-procesing In A Container :
Those who are not fortunate enough to have a patch of garden, can have a 80 cm x 60 cm x 40 cm wooden box (with few drainage holes), kept in a balcony or on the terrace. 5 kg vermicastings should be applied,in a layer, on a newspaper, kept at the bottom and daily

household organic wastes should be put in the box. Put some water occasionally till just a few drops come out from the drain.

A container of this size will take a year to get filled, by a family of four. At any time, one will notice a black decomposed mass below the top 100 mm raw layer. Lower layers can be removed and used as a rich organic fertilizer for potted plants.

3. Collection of Wastes and Central Vermi-processing Facilities : Separated organic wastes can be collected in specially designed bins. These bins have a layer of vermicastings on the soil bottom. Periodically, the odour-free organic matter can be transported to the vermi-processing facilities for further processing and marketing of the organic fertilizer produced.

In short, MSW problem can be effectively tackled by :

1. Motivating the individuals to practise separation at source
2. Resource-recycling through ragpickers (resource recycling agents)
3. Individual bio-processing or central vermi-processing for organic fraction.

Any methodology away from such resource recycling is likely to create pollution.

Hundreds of families in Pune are enjoying tension-free gardening by recycling kitchen wastes and garden wastes back to the soil through vermiculture biotechnology. For them, MSW is a resource - not to be dumped into the municipal garbage bins, already overflowing with stinking and polluting mass.

2.1.2 Human Excreta :

BERI Vermi-processing Toilet (BVT), field-tested since 1982, is a novel low water-use toilet for safe processing of human excreta without odour and fly problem.

BVT consists of a superstructure, squatting platform and a vermi-processing pit (Fig.4). Water-seal is eliminated and a sloping channel (slope more than 45^0) is constructed to facilitate transport of human excreta to the vermi-processing pit with a minimum quantity of water (1-2 liters per use). The pit is provided with a removable cover with ventilation holes.

Vermi-processing pit should be so located that the water table is more than 2 m below the pit bottom. It should be away from a water-well by 10-15 m. Low lying areas which are likely to be flooded during the rains should be avoided.

BERI Vermi-processing Toilet

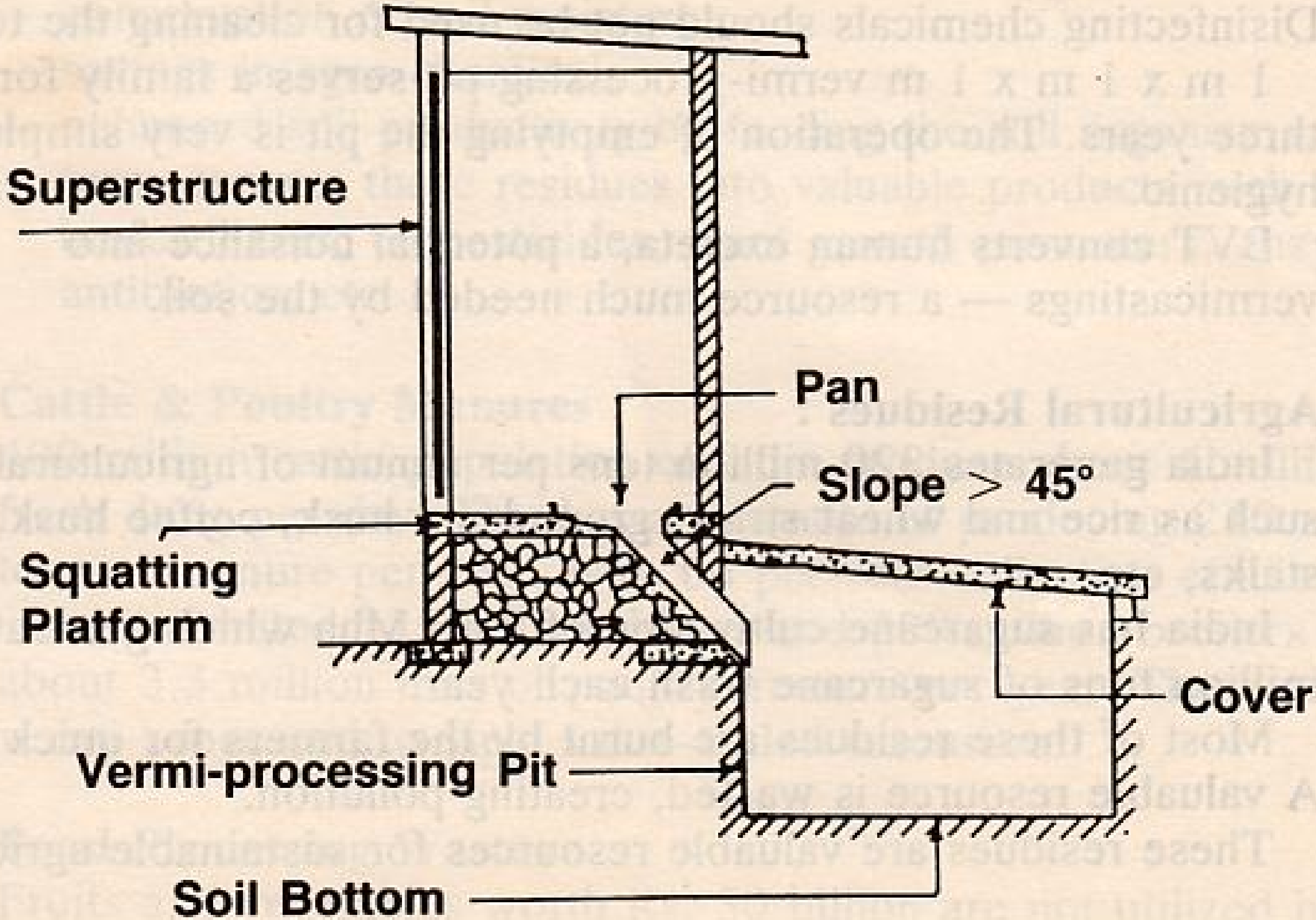


Figure 4

BVT is commissioned by putting 5 kg vermicastings in the pit. It is advisable to wet the pan before use so that the excreta does not stick to the pan. This reduces the water-requirement of the toilet. Disinfecting chemicals should not be used for cleaning the toilet.

1 m x 1 m x 1 m vermi-processing pit serves a family for about three years. The operation of emptying the pit is very simple and hygienic.

BVT converts human excreta, a potential nuisance into vermicastings — a resource much needed by the soil.

2.1.3 Agricultural Residues :

India generates 320 million tons per annum of agricultural residues such as rice and wheat straw, ground-nut husk, coffee husk, cotton stalks, etc.

India has sugarcane cultivation of 2.66 Mha which generates 26.6 million tons of sugarcane trash each year.

Most of these residues are burnt by the farmers for quick disposal. A valuable resource is wasted, creating pollution.

These residues are valuable resources for sustainable agriculture,

and in the recent past, thousands of farmers have started applying these in the form of mulches, 100 mm thick, to get several benefits, such as :

— conservation of soil moisture
— savings in agro-chemicals
— enhanced soil productivity by feeding the soil organisms, which in turn, convert these residues into valuable products such as biofertilizers, biopesticides, plant growth promoters, enzymes, antibiotics, etc.

2.1.4 Cattle & Poultry Manures :

400 million cattle population of India produce about 4 million tons of fresh dung per day. This has a potential of producing 210 million tons of manure per year, with 66 per cent collection efficiency.

An estimated 125 million layers and 200 million broilers produce about 3.3 million tons of poultry manure per year. These could be vermi-processed to yield value-added resources.

2.1.5 Food-Processing Wastes :

Fruits and vegetables worth Rs. 30 billion are not utilized in India

VERMICULTURE BIOCONVERSION OF SOLID WASTES

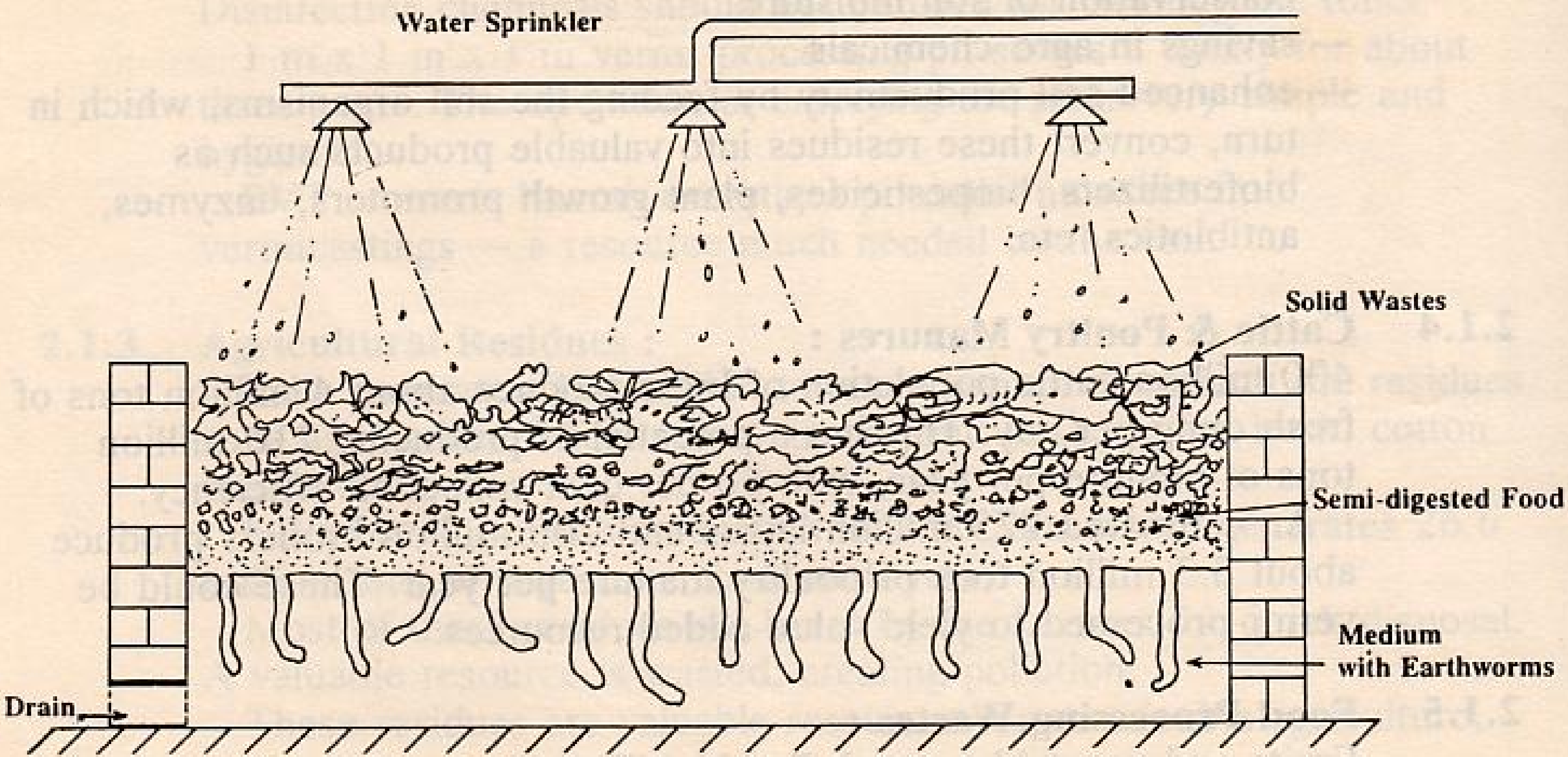


Figure 5

every year because of spoilage. Only 10 per cent of the fruits and vegetables grown in India find its way to the processing industry as against 70 per cent in Brazil and 83 per cent in Malaysia.

This clearly shows the growth-potential for the food-processing units, particularly in view of the recent incentives for processing and export.

350 sugar mills and 3000 slaughterhouses produce valuable residues which need to be utilized productively.

Vermiculture biotechnology is being applied to set up vermi-processing facilities at such units where the residues are converted into vermicastings, a resource for sustainable agriculture.

2.2 Wastewater Management :

A problem can be easily solved by just not creating it. Many times, wastewater is produced by washing a solid waste with copious amounts of drinking quality water (as in modern sewage handling systems). Wastewater is also produced by scrubbing polluting gases with sprays of water.

In such cases, we have just changed a solid or gaseous waste into liquid waste (wastewater).

Since water is scarce, it is advisable to treat a solid waste without dilution. Similarly, wherever possible, dry methods should be used for cleaning the gaseous streams.

2.2.1 Conventional Wastewater Treatment

Human excreta, basically a solid waste, is diluted with 200 volumes of drinking quality water to produce sewage which has only 0.1 per cent solids.

147 class I cities (population more than 1 lakh) generate 7000 MLD sewage, out of which only 2700 MLD is treated.

198 class II cities (population 50,000 — 99,999) generate 1200 MLD sewage, out of which only 66 MLD is treated.

Out of India's 3,119 towns and cities, only 209 have partial sewerage and sewage-treatment facilities and eight have full facilities. On the river Ganga alone, 114 cities, each with 50,000 or more inhabitants dump untreated sewage into the river each day.

Overall, 80 per cent of sewage in India goes untreated to lakes, rivers or seas to create further problems. In 20 per cent cases, electricity is spent to convert the liquid stream back into a solid stream (sewage sludge) which again poses pollution problems. Treated sewage, too, has nutrients (N & P) which are needed by the soil. However it goes to surface water-bodies to create eutrophication (proliferation of water hyacinth, for example).

350 sugar mills and 212 distilleries in India produce wastewaters with considerable pollution potential.

Small-scale dairies, slaughter-houses, tanneries and pulp & paper mills can not treat their wastewaters, in absence of a cost-effective appropriate technology.

2.2.2 BV Process for Wastewater Treatment :

Bhawalkar Earthworm Research Institute (BERI), Pune, India has developed an unique BV (BERI Vermifilter) process for cost-effective

treatment of organic wastewaters, namely :
— Sewage
— Dairy wastewater
— Sugar mill wastewater
— Distillery spent-wash, raw or after biomethanation
— Pulp & paper wastewater
— Food-processing wastewater
— Fermentation industry wastewater
— Tannery wastewater, etc.

These are used as valuable raw materials by the BV Process to produce:
— Vermicastings, an effective biofertilizer, and
— Water for recycle or reuse.

BV Process (Figure 6) :
— Wastewater is pretreated, if necessary, to make it acceptable to earthworms.
— Vermifilters consist of an active biomass of earthworms in specially developed medium.
— Wastewater is made to trickle through the highly adsorbent medium.

BV PROCESS FOR WASTEWATER TREATMENT

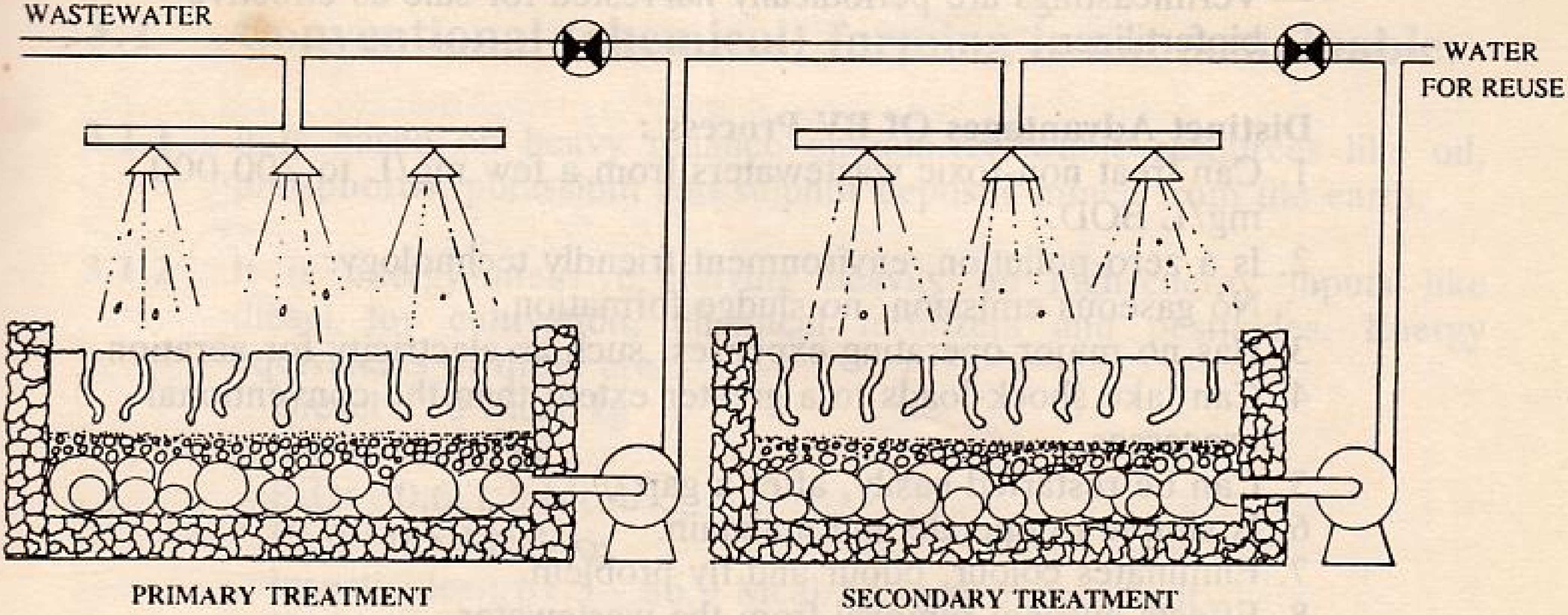


Figure 6

— Partially treated water drains out.
— Impurities are adsorbed on the medium and are vermistabilized into vermicastings.
— Vermicastings are periodically harvested for sale as effective biofertilizer.

Distinct Advantages Of BV Process :

1. Can treat non-toxic wastewaters from a few mg/L to 200,000 mg/L BOD.
2. Is a zero-pollution, environment-friendly technology. No gaseous emission, no sludge formation.
3. Has no major operating expenses, such as electricity for aeration.
4. Can take shock-loads to a greater extent than the conventional processes.
5. Can be restarted easily, after a gap.
6. Is simple to operate and maintain.
7. Eliminates colour, odour and fly problem.
8. Effects nutrient removal from the wastewater.
9. Offers shorter pay-back period.

3. Vermiculture Biotechnology For Sustainable Agriculture

3.1 Conventional (chemical) farming is not sustainable:

3.1.1 It is based on heavy reliance on non-renewable resources like oil, phosphorus, potassium and sulphur deposits mined from the earth.

3.1.2 It is energy-intensive, relying heavily on high-energy inputs like diesel for cultivation, chemical fertilizers and pesticides. Energy equivalents of these are :

Diesel : 10 Mcal/kg
N : 15 Mcal/kg
P_2O_5 : 0.6-1.5 Mcal/kg
K_2O : 0.5 Mcal/kg
Insecticides : 61.5 - 86.9 Mcal/kg, active ingredient
Herbicides : 62.8 - 99.2 Mcal/kg, active ingredient
Fungicides : 27.8 -64.9 Mcal/kg, active ingredient.

3.1.3 Energy Ratio (ER), between the energy content of the food output from the system and the gross energy requirement for its production, is low. For example, ER for corn in the USA is 2.8. It can be improved by cutting down energy- intensive inputs and making judicious use of organic wastes.

3.1.4 Most of these non-renewable inputs are imported by most of the developing countries and the prices (in dollars) fluctuate widely, disrupting the economic projections. Agricultural produce like tea, coffee, tobacco, sugar, jute, bones, oil-cakes etc. are exported at a lesser price to meet the balance of payment (BoP). For increase in the oil price by a dollar per barrel, India spends, 5 billion rupees more per year of foreign exchange (with the current exchange rate of Rs. 30/- per dollar).

3.1.5 To make such products affordable to the farmers, fertilizer subsidy which was introduced in a small way in 1977-78 (Rs 250 million) went up 175 times in 1990-91 (about Rs. 44 billion), putting increasing pressures on exchequer. Withdrawal of subsidies, on the other hand, results in increase in the cost of farm-inputs and lesser profits.

3.1.6 Present agricultural practices in many cases lead to "mining" of the soil. The soil-losses of cropland alone are estimated to be 2 billion tons, annually, in the USA. India loses 5.3 billion tons (about 16 tons/ha) of rich topsoil each year. Present average rates of erosion usually exceed the average rate of soil formation by 10:1. The erosion of soil is so great that by the end of the century there will be one-third less soil per person than there is now. Losses of soil result in decreased productivity. Up to now, these losses have been offset by increased chemical fertilizer additions. However, the increasing costs of fertilizers and long-term implications of their heavy usage decry the wisdom of this approach. Erosion also causes water pollution. Sediment is rated as the biggest agricultural pollutant.

3.1.7 Chemical farming leads to higher water use, leading to groundwater depletion. Groundwater is essentially being mined, resulting in escalating costs of irrigation. Heavy withdrawal of groundwater also in some instances results in saltwater contamination of the fresh water in the aquifer near the coast.

3.1.8 Heavy reliance on soluble chemical fertilizers results in nutrient-rich run-offs, reaching water bodies. Nutrients, especially nitrogen and phosphorus, lead to eutrophication. These two nutrients accelerate algal growth. In turn, death of the increased algal mass leads to oxygen depletion as oxygen-consuming micro-organisms consume the algae. Eventually, fish die and the recreational/food value of the water is diminished.

3.1.9 Nitrate, in runoff, ultimately appears in groundwater. This can be a serious health problem, as nitrate sensitivity (methemoglobinemia) occurs in, infants up to 3 months of age.

Continued drinking of nitrate-contaminated water may also lead to the formation of carcinogenic nitrosamines.

3.1.10 Salinization is assuming a serious scale. As irrigation water is evapotranspired, salts are left behind in the topsoil. These salts increase in concentration, and if uncorrected, reach a concentration that reduces crop productivity. Poor drainage and irrigation water, contaminated with salt water, or having high levels of soluble salts,

from fertilizer run-off, accelerate salt accumulation. Table 3.1 shows the salinization problem over the world. Salinization can cause saline contamination of groundwater and surface water, and subsequent damage to surface-water ecosystems.

Table 3.1 Salinization Over The World

Country	Area Damaged Mha	Share Of Irrigated Land %
India	20.0	36
China	7.0	15
USA	5.2	27
Pakistan	3.2	20
Soviet Union (former)	2.5	12
Total	37.9	24
World	60.2	24

(Source : Brown, L.R.et al. (1990), State of the World, W.W.Norton & Co., New York)

3.1.11 Pesticides (biocides) are posing threats to the environment :

— Pesticides do not know when to stop killing. They poison the whole ecosystem - birds, predator insects, frogs, honeybees, beneficial soil microflora and earthworms. They seep into groundwater resulting in groundwater contamination of an almost permanent nature. Drinking water generally contains more than 16 toxic pesticides.

— Pesticides do not seem to be improving agricultural yield. Farmers are still losing about the same percentage of their crops due to pests as they did before the use of pesticides.

— Over 100 active pesticide ingredients are known to cause birth defects, cancer and gene mutation.

— Sooner or later, targeted pests develop resistance to a specific pesticide, rendering the chemicals worthless. More than 500 species of insects and mites, and 70 types of fungi are now resistant to pesticides.

— Though developing countries use less than one-quarter of the world's pesticides, they suffer three-quarters of all pesticide fatalities. According to Oxfam, 375,000 people in the Third World are poisoned - 10,000 fatally- by pesticides each year. These figures do not include chronic or long-term damages such as cancers, birth defects

or sterility, nor do they include suicide poisonings.

— Some pesticides, because of their water insolubility, tend to accumulate in the fatty tissues of plants and animals as they move through the "food chain", posing danger to birds and man who are at the top of the food-chain. DDD was applied in Clear Lake, California at levels of 14 parts per billion to control gnats. Although this treatment relieved the lakeside of its gnat problem, the compound ultimately became part of the aquatic food chain and was concentrated to levels 80,000 times greater than the original – a concentration strong enough to kill fish-eating birds.

— Pesticides are persistent in nature and stay for years. Though DDT was banned in the USA in 1972, it is still found in vegetables and fruits sold in American supermarkets, as well as in mother's milk, in much larger concentration than what is tolerable.

"Many or most of the countries subsidising the use of water, chemicals in agriculture and energy - are thus encouraging overuse, waste and pollution."

— World Resources Institute, Washington D. C. (1989)

Dr. M. S. Swaminathan, the world renowned agricultural scientist had cautioned, way back in 1968, when the green revolution was just taking shape :

"Intensive cultivation of land without conservation of soil fertility and soil structure would lead ultimately to the springing up of deserts. Irrigation without arrangements for drainage would result in soils getting alkaline or saline. Indiscriminate use of pesticides could cause adverse changes in biological balance as well as lead to an increase in the incidence of cancer and the other diseases, through the toxic residues being present in the grains or other edible parts. Unscientific tapping of underground water would lead to the rapid exhaustion of this wonderful capital resource left to us through ages of natural farming. The initiation of exploitative agriculture without a proper understanding of the various consequences of every one of the changes introduced into a traditional agricultural system and without first building up a proper scientific and training base to sustain it may only lead us into an era of agricultural disaster in the long run, rather than to an era of agricultural prosperity."

3.2 What Is Sustainable Agriculture ?

Worldwide there is an increasing awareness about alternative/natural/biological/organic/sustainable agricultural practices in view of energy shortages, food safety and environmental concerns, arising out of conventional (chemical) farming. Whatever be the name, this alternative system avoids or largely excludes the use of synthetic fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible, this system relies upon:

— efficient recycling of crop residues, animal manures, green manures, off-farm organic wastes - reducing their pollution potential, simultaneously
— minimum mechanical cultivation, to maintain soil productivity and tilth
— mineral-bearing rocks to supply plant nutrients
— increase in the pest-resistance through balanced nutrition of the plants
— biological pest control
— crop rotation
— mixed cropping.

Sustainable agriculture is one in which the goal is permanence achieved through the utilisation of renewable resources. Basic elements of sustainable agriculture are conservation of energy, soil and water.

That is — for a farm to be sustainable it must produce adequate amounts of high quality food, protect its resources and be both environmentally safe and profitable. Essential to achievement of conservation are agricultural practices that are directed towards renewability and non-pollution of resources. This does not mean simply a return to primitive agriculture, with the complete elimination of agrochemicals, but use of efficient mechanisms of soil biotechnology.

3.3 Sustainable Agriculture In The USA :

Large number of American farmers are questioning the environmental, economic and social impacts of conventional chemical agriculture. Consequently, many of them are seeking alternative practices that would make agriculture more sustainable. According to the U. S. Department of Agriculture estimate, between 90,000 to 1,00,000 farmers — about 5% of nation's total — are practising sustainable agriculture today.

Farmers, who practise soil conservation and reduce their dependence on fertilizers and pesticides, generally report that their production costs

are lower than those of nearby conventional farms. Sometimes the yields from sustainable farms are somewhat lower than those from conventional farms, but they are frequently offset by lower production costs, which leads to equal or greater net returns.

The USDA commissioned a study in 1979 to assess the extent of organic farming in the USA, as well as the technology behind the farming and its economic and ecological impact. The study, "Report and Recommendations on Organic Farming", published in 1980 was based heavily on case studies of 69 organic farms in 23 states.

The USDA report concluded that organic farming is energy-efficient, environmentally sound, productive and stable and tends toward long-term sustainability. Since the report was published, it has stimulated interest, both in the USA and outside, in sustainable agriculture. Its recommendations provided the basis for the alternative agriculture initiative passed by the U.S. Congress in the Food Security Act of 1985, which calls for research and education on sustainable farming systems.

The sustainable agriculture movement received a further boost in September1989 when the Board on Agriculture of National Research Council of the USA released another study, "Alternative Agriculture". The report is perhaps the most important confirmation of the success

of farms that rely on biological resources and their beneficial interactions instead of chemicals. It found that well-managed farms growing diverse crops with little or no chemicals are as productive and often more profitable than conventional farms. It also asserted that "wider adoption of proven alternative systems would result in even greater economic benefits to farmers and environmental gains for the nation."

3.4 Towards Sustainable Agriculture :

There are numerous sustainable farms around the world. They have consistently produced yields comparable to chemical agriculture, year after year. Their net returns are higher, by 15-20 percent, with reduced inputs.

However, the change-over from chemical to sustainable agriculture is difficult. Farmers have to forego yields for 3-5 years, till their soil productivity is built up by recycling of organic matter. Few farmers can bear this loss. The planners, too, cannot accept lesser food production to feed the growing population.

Hence, the biggest challenge we have at present is : how to change the farming system without a significant loss of yield ?

3.5 Quick Change-over To Sustainable Agriculture :

It is possible to effect a quick change-over to sustainable agriculture by harnessing vermiculture biotechnology to the soil.

Good earthworm population is a measure of soil productivity. Hence, establishing an earthworm population of 0.2-1.0 million per hectare within a year is the key to a quick change-over without a significant loss of yield. Different consideration in this regard are :

1. Worms should be of deep-burrowing type (endogees), those possessing digging muscles, enabling them protect from harsh field conditions.
2. Burrowing worms show high mortality when shifted from one place to another, due to environmental shock. Hence, they should be hatched in the new environment, from vermicastings containing worm cocoons and beneficial soil microflora.
3. The package should be simple and cost-effective to the farmers.

Bhawalkar Earthworm Research Institute (BERI), Pune, India, has developed a cost effective, practical package for a quick changeover to sustainable agriculture without a significant loss of yield. Farmers from diverse agro-climatic regions have successfully adopted this package on diverse crops.

The package consists of :

— Applying first a layer of vermicastings at the rate of 2.5 tons per ha (costing, about Rs. 4,500 to 5,000 per ton at present).

Vermicastings are applied only in areas where sufficient moisture is present, like basins below trees, below drippers or in furrows (in case of crops grown in ridge-and-furrow beds).

— Feeding earthworms with fresh animal dung, in 20 mm layer, below the mulch, if possible.

— Watering every 15-20 days, as the mulch reduces moisture loss from the soil.

— Periodic application of dung & mulch as they are consumed.

Organic materials like weeds (uprooted when fully grown), agricultural residues, city wastes or food-processing wastes can be used for mulching.

Worms hatch out within a month. They start processing the organic mulch and produce vermicastings, in situ. No further doses are, ideally, required to be added, if the above mentioned procedure is followed religiously. This makes the package cost-effective to the farmers.

3.6 Soil Biotechnology (Figure 7) :

— Worms build up density of beneficial bacteria and actinomycetes, 1,000 times inside their guts, by providing optimum conditions of temperature, moisture, aeration and pH.

— Worms also produce several enzymes which split complex polymers, in wastes, into simple molecules, which are further utilised by the soil micro-organisms.

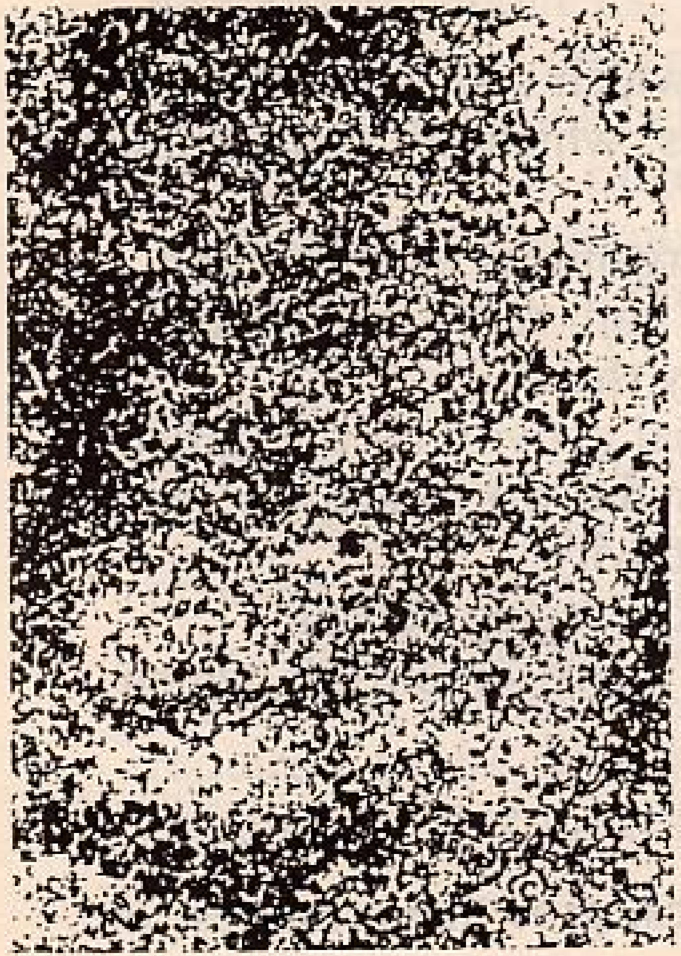
— Worms assimilate some of the micro-organisms as their food. Hence, more the microbial biomass in the soil, more will be the worm biomass, which can be supported by the soil.

Though a farmer cannot see the microbial activity by the naked eyes, he can see the worm activity. Higher the worm activity, better the microbial action, leading to soil productivity.

— Worms enrich the soil with oxygen, encouraging aerobic micro-organisms. These are mostly useful micro-organisms which perform several important functions like :

- — N-fixation
- — Nitrification
- — Production of enzymes, antibiotics, growth-hormones, etc.

THE EFFECT OF EARTHWORMS ON THE SOIL



With earthworms; soil is granulated, light, crumbly; absorbs water; gives plant life & chance to grow normally.

Soil heavy, packed, almost impervious to water. Cakes under hot sun; hard to cultivate; Restricts plant and root growth. **No earthworms.**

Figure 7

— Pathogens are destroyed due to proliferation of these beneficial soil micro-organisms.

— Other troublesome organisms, like nematodes, are reduced by worm action.

— Normal microbial biomass, about 1 ton per ha, acting in the top 30 cm, is boosted by the worms to 10 tons per ha, acting in 3 m depth of the soil. Worm biomass corresponding to this microbial biomass will be about 1 ton per ha. Hence a farmer can have a work-force of 11 tons of biomass, per ha, working quietly underground, day and night. This can be compared to the 1 ton biomass, of two bulls, doing conventional cultivation, above ground.

3.7 Biotechnological Farming Practices :

3.7.1 Cultivation :

Mechanical cultivation, normally reaching a depth of 30 cm only, is replaced by cultivation (upto 3 m) by soil organisms and plant roots.

3.7.2 Weeding :

As long as weeds do not compete with the main crop, for sunlight, they are allowed to grow. They are then periodically cut and used for mulching (feed for the soil organisms). No herbicides are used.

3.7.3 Fertilizers :

Fertilization is through soil biotechnological processes. Diverse organic wastes are utilized as raw materials to produce balanced fertilizers for the plants.

3.7.4 Pesticides :

Plants develop pest-resistance by balanced nutrition provided by the soil organisms. Biological control of pests and the use of environment-friendly herbal pesticides (such as neem-extract) are also encouraged.

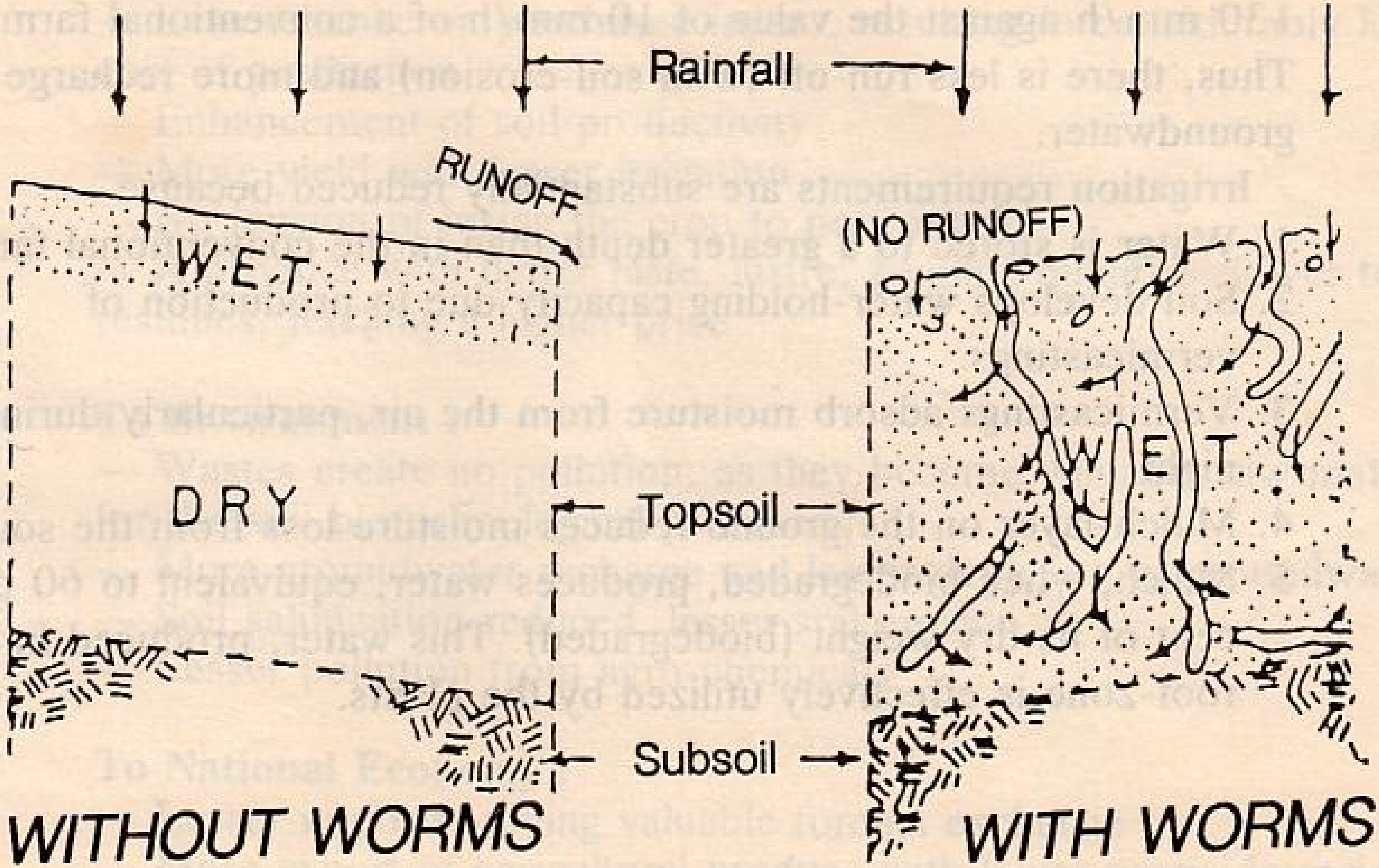

Rainfall
RUNOFF
WET
(NO RUNOFF)
DRY
WET
Topsoil
Subsoil
WITHOUT WORMS
WITH WORMS

Figure 8

3.7.5 Irrigation (Figure 8) :

Worm-action increases water - infiltration capacity of the soil upto 130 mm/h against the value of 10 mm/h of a conventional farm soil. Thus, there is less run-off (with soil-erosion) and more recharge of groundwater.

Irrigation requirements are substantially reduced because —

1. Water is stored to a greater depth than in the conventional farm.
2. Soil develops water-holding capacity due to production of vermicastings.
3. Vermicastings adsorb moisture from the air, particularly during the night.
4. Mulch-layer on the ground reduces moisture loss from the soil.
5. Mulch, when biodegraded, produces water, equivalent to 60 per cent of its dry weight (biodegraded). This water, produced in the root-zone is effectively utilized by the plants.

3.8 Benefits Of Sustainable Agriculture :

To Farmers :

— Less reliance on purchased inputs, resulting in considerably low cost of production
— Enhancement of soil productivity
— More yield with lesser irrigation
— No tension of losing the crop to pest-attack
— A produce with better taste, lustre, keeping qualities, lower toxic residues, fetching a higher price

To Environment :

— Wastes create no pollution, as they become valuable raw materials for the soil biotechnological processes.
— More groundwater recharge and lesser depletion of groundwater
— Soil salinization reduced, lesser soil erosion
— Lesser pollution from agro-chemicals

To National Economy :

— Lesser imports, saving valuable foreign exchange
— More export of agricultural produce with lower pesticide residues

4. Vermiculture Biotechnology For Wasteland Development

A land which remains barren is termed as a wasteland. Two-third of the potentially productive land (266 Mha), of the total land (304 Mha) of India is subject to some form of degradation. 90 Mha is officially declared as wasteland by the National Wasteland Development Board.

Increasing wasteland formation, coupled with the population growth has resulted in reduced per capita land availability for cultivation :

Year	Per Capita Land For Cultivation
1951	0.48 ha
1981	0.20 ha
2000	0.14 ha

4.1 Causes Of Wasteland Formation :

— Neglected agriculture on marginal and poor soils
— Shifting cultivation on hill-slopes
— Lack of soil and moisture-conservation practices in agriculture
— Destruction of ecology by mining, electrification, construction and other industrial projects
— Excessive irrigation, with poor drainage and overuse of chemicals
— Overgrazing by animals
— Increased demand for forest products, leading to deforestation
— Neglect of commons (village and government owned lands)

Vermiculture biotechnology has a potential of correcting some of these causes and arresting the speed of wasteland formation.

4.2 Types Of Wastelands And Their Development :

4.2.1 Shallow Soils — can be developed by :

— plantation of trees along contours
— application of 2 kg vermicastings per pit
— application of 100 mm mulch over the layer of vermicastings,

preferably after applying 20 mm layer of dung
— watering, as needed
— subsequent mulching with grass/weeds cut from the interspaces between the trees.

4.2.2 **Sand Dunes** — can be brought under vegetation of xerophytes by a procedure as detailed above.

4.2.3 **Saline And Alkali Soils** — can be effectively improved by planting salt-tolerant trees and adopting the procedure given in 4.2.1 with application of 5 kg vermicastings per pit.

4.2.4 **Drought Affected Areas** — should brought under tree plantation suitable to dry-farming, with an application of vermicastings and mulch.

CASE STUDIES

CASE 1 : SUCCESSFUL SUGARCANE FARMER

Krishnat L. Phule

Aasu (Phone : 39), Tal. Phaltan

Dist. Satara, Maharashtra

- Applied vermiculture biotechnology in 1988, on sugarcane on saline soil. Irrigation with saline groundwater. Gradually expanded to 2 ha with successful results.
- Plot on vermiculture yielded 125 tons/ha of sugarcane from plantation crop as well as from two ratoons.
  Control with chemicals and FYM yielded 100 and 75 tons/ha from plantation and the first ratoon respectively. Second ratoon was not taken.

Net Profit, Rs./ha :

	Vermiculture Plot	Chemical Plot
Plantation Crop	28,750	26,250
First Ratoon	46,250	18,750
Second Ratoon	46,250	—

- Results of soil-analysis showed marked improvements in the soil productivity within a year. The vermiculture plot had :
  37% more N
  66% more P_2O_5
  10% more K_2O
  50% less electrical conductivity
  46% less chlorides, than the chemical plot.
  (Jambhekar H. A. & Bhiday M. R. (1991), Development Communication with Rural Masses, Ph. D. Thesis, Univ. of Poona, Pune)
- Vermiculture produced sugarcane with 3-4 extra brix and lesser salts.

5.2 CASE 2 : SUCCESSFUL GRAPE FARMER

Jayant V. Barve
Vita (Phone : 141). Dist. Sangli, Maharashtra

- Grape planted on eroded wasteland.
- Basal application of vermicastings costing, Rs. 10,000/ha
- Cowdung and agricultural residues (including fully grown weeds raised as intercrop) used for mulching.
- No chemicals put in the soil, but sprayed on foliage, according to the need.

Results :

- The orchard was healthy throughout and there were no nutrient deficiencies visible.
- 15 pesticide sprays (of lesser concentration) were applied in the first year - against 70-80 sprays normally (in chemical farming). The number of sprays went down in the second year.
- Yield was normal, however better price fetched due to superior quality (lustre, taste, higher shelf-life etc.). 90 per cent of the produce was exported.

- Input costs reduced from Rs. 1 lakh to Rs. 40,000 per ha.
- There was 75% saving in the water requirement of the crop.
- Periodic soil-analysis showed drastic improvements in the soil fertility :

★ Original pH	:	8.3
Afer 6 months	:	7.4
After 12 months	:	6.9
★ Original available potash	:	62.5 kg/ha
After 6 months	:	252 kg/ha
After 12 months	:	800 kg/ha

Petiole analysis, on 45th day from the date of October pruning showed increased concentrations of nutrients :

K was 2.5% (against 1.0% normally)
Fe was 677 ppm (against 200 ppm)
Cu was 203 ppm (against 78 ppm)
Ca was 2.15% (against 1.5%)
Mg was 1.22% (against 0.36%)

5.3 CASE 3 : SUCCESSFUL VEGETABLE FARMER

Madhusoodan G. Khamkar
Bhandgaon (Bavda), Tal. Indapur
Dist. Pune, Maharashtra

- Tondali (Coccinia cordifolia) planted on saline soil
- Irrigation with saline groundwater

Results :

- pH improvement from 8.2 to 7.3 in 1 year
- Increase in water-holding ability of the soil
- Improvement of the soil-structure
- Disappearance of salt-crustation on the surface
- Produce with better quality, fetching 30 per cent higher price
- Performance of 3 years (with chemicals) and 2 years (with vermiculture) is summarised as follows :

Chemical Plot		**Vermiculture Plot**	
Inputs : For 1 acre	Rs./Year	Inputs : For 1 acre	Rs./Year
1. Chemical fertilizers	2,700	1. Vermicastings (divided over 5 years)	800
2. Organic fertilizers	2,340	2. FYM, 15 Cartloads	450
		Organic fertilizer	980
		Mulching	500
3. Pesticide Sprays 18 Nos. x 100	1,800	3. Pesticide Sprays 6 Nos. x 100	600
4. Weeding (6 times x 250)	1,500	4. Weeding	—
5. Cultivation (3 times x300)	900	5. Cultivation	—
6. Irrigation (33 times x 15)	495	6. Irrigation (23 times x 15)	345
Total Inputs	9,735	Total Inputs	3,675

	Rs./Year
Soil depreciates	+ 1,000
Real Expenditure	10,735
Average yield : 23,800 kg	
Returns (@ Rs.2/kg)	47,600
Expenditure	10,735
Profit	36,865

	Rs./Year
Soil appreciates	— 1,000
Real Expenditure	2,675
Yield : 22,710 kg	
Returns (@ Rs.2.6/kg)	59,046
Expenditure	2,675
Profit	56,371

6. About Ourselves :

Bhawalkar Earthworm Research Institute (BERI) was established in 1981 by Mr. Uday S. Bhawalkar (a chemical engineer from IIT Bombay), and Mrs. Vidula U. Bhawalkar (an electronic engineer).

Objective :

To apply vermiculture biotechnology to :

— Environmental protection, and

— Sustainable agriculture, wasteland development.

Background :

In order to achieve the said objective :

— BERI evolved processes for solid and liquid wastes management over 8 years of practical work at the site of Mr. Bhawalkar, the director. This was followed by his involvement in the Ph.D. work related to vermiculture biotechnology at the Indian Institute of Technology, Bombay.

Recognitions :

— Mr. Bhawalkar was honoured by the prestigious Rolex Award for Enterprise Secretariat by his inclusion in their book - "Spirit of Enterprise - 1990".

— BERI received an "Outstanding Exhibit" - award at the National Fair on Water Management in Agriculture, Madras, March 1990. The exhibit was a live demonstration of purification of wastewater by the BV process to get water for irrigation and vermicastings, the effective biofertilizer.

— Mr. Bhawalkar was honoured by Rotary Club of Pune Central, June 1992 for his contribution to environmental protection of the city of Pune, by motivating individual families — with active support from the Save Pune Citizens Committee — to recycle kitchen and garden residues, with vermiculture biotechnology.

— Mr. Bhawalkar was appointed as a member of the "Committee On Sustainable Agriculture", set up by the Government of Mahara-

shtra. The committee has strongly recommended the government to popularize effective recycling of agricultural residues by the farmers, to cut down the non-renewable external inputs.

— BERI was honoured in July 1992, by the Late Shri Sharad Kelkar Memorial Award Committee, instituted by State Industrial And Investment Corporation Of Maharashtra (SICOM) with a cash award and a certificate of recognition, for BERI's research related to industrial waste-management with vermiculture biotechnology.

— BERI was invited by the Rotary Club Of Makati Ayala, Metro Manila, The Philippines, to conduct a seminar on "Waste Managment With Vermiculture Biotechnology", in November 1992.

— BERI has been awarded a contract to design 'sewage treatment plant through vermiculture for small communities' by the Central Pollution Control Board, New Delhi.

— In addition to more than 30 national seminars, Mr. Bhawalkar presented papers in 9 international conferences, namely :

1. Water & Wastewater 1990 Conference,
   Barcelona, Spain, April 1990
2. 4 th International Symposium on Earthworm Ecology,
   Avignon, France, June 1990
3. Food Industry Environmental Conference,
   Atlanta, USA, November 1990
4. Low External Input Sustainable Agriculture (LEISA) Conference,
   Amsterdam, The Netherlands, April 1991
5. International conference on Appropriate Waste Management Technologies,
   Perth, Australia, November 1991
6. Management of Wastes and By-product Utilization in Agro-industrial and Llivestock Units,
   AGRO-UETP Conference, Athens, Greece, February 1992
7. UN-APCTT Workshop on Waste Management and Waste Recycling in Developing Countries,
   Bombay, India, May 1992
8. XI International Colloquium on Soil Zoology,
   Jyvaskyla, Finland, Auglust 1992
9. Bio-Tech 92, International Conference on Biotechnology
   Bangalore, October 1992.

Present Activities :

BERI undertakes, on turnkey basis, the setting up of plants for solid and liquid wastes management, aimed at treating non-toxic organic wastes from cities, dairies, sugar mills, distilleries, slaughterhouses, tanneries, pulp and paper mills and various food-processing units.

BERI continues to be actively involved in sustainable agriculture and wasteland development. Vermiculture biotechnology is being successfully used by farmers on diverse crops such as - sugarcane, grape, guava, banana, coconut, pomegranate, chickoo, ber, vegetables etc., in different agro-climatic conditions in India.

Biotech Consortium India Limited (BCIL), New Delhi, set up by the Department of Biotechnology (DBT) and all India financial institutions (led by IDBI), has also identified vermiculture as potential appropriate biotechnology.

BERI has entered into an association with BCIL to actively promote this technology in India through its techno-financial linkages with technical/research institutions, government agencies/departments and industries.

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Discover yourself how the worms

- reduce soil erosion
- improve the soil productivity
- help in wasteland development
- help groundwater-recharge
- protect groundwater from getting polluted
- can get rid of wastes to produce resources
- reduce dependence on imported, energy-rich chemicals
- help economy of The Third World countries.

It may be doubted whether there are many other animals which have played so important a part in the history of the world, as have these lowly organised creatures (worms).

— Charles Darwin (1881)